Disaster mitigation due to next Nankai earthquake tsunamis occurring in around 2035

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Abstract. Earthquake occurrences in western Japan are caused by earthquakes beneath the sea along the Nankai trough. This trough averages 4000 m in depth off the Kii peninsula that runs east to west, off about 100 km from Shionomisaki cape, with its eastern tip reaching into Suruga Bay. Here the northerly Philippine Sea plate is slipping and subducting beneath the Eurasia plate at an average speed of 4 to 5 cm/year, and is believed to have been doing so for several million years. When this slippage exceeds a total of about 5 m, a rupture occurs, creating a M 8–8.6 earthquake. The "urban tsunami disaster" due to occur following a Nankai earthquake is expected to strike a wide area that includes many modern coastal cities and ports, resulting in a disaster of unprecedented proportions. Consequently, it will be very difficult to apply the lessons of past tsunami disasters if an expansive area including residential coastal towns as well as low-lying large urban regions with populations of hundreds of thousands or millions of people is hit by a tsunami. This paper presents disaster scenarios and tsunami disaster reduction methods that are necessary for producing a long-term tsunami measure policy and which, more importantly, have not yet been encountered in actual tsunami disasters.

1. Introduction

Earthquake occurrences in western Japan are caused by earthquakes beneath the sea along the Nankai trough. This trough is a trench averaging 4000 m in depth in the Kii peninsula that runs east to west, with its eastern tip reaching into Suruga Bay. Here the northerly Philippine Sea plate is slipping and subducting beneath the Eurasia plate at an average speed of 4 to 5 cm/year, and is believed to have been doing so for several millions of years. When this slippage exceeds a total of about 5 m, a rupture occurs, creating a M 8–8.6 earthquake.

We have a long period of historical records on Nankai earthquakes and tsunamis. The oldest document we find is on the 684 Nankai earthquake tsunami. Of course, the particulars on damage are not clear, but we can understand the huge extent of damage. After that, seven other gigantic tsunamis have hit our western coast facing the Pacific and Seto Inland Sea. The interval between tsunami disasters ranges from about 100 to 150 years as shown in Fig. 1. The earthquake magnitude is 8.4 or more except for the 1946 quake, which was 8.0.

This earthquake is typically a twin earthquake with the Tokai one. They occur simultaneously or in almost 2-year intervals. Usually, a Nankai earthquake will occur after a Tokai earthquake (in seven events, the Tokai earthquake occurred first, and in only one case it was not clear). This subduction process in plate boundaries is very simple so that most of our seismologists hope to predict the next Tokai and Nankai earthquakes. Fortunately, the magnitude of the last Nankai earthquake was 8.0 so that earthquake

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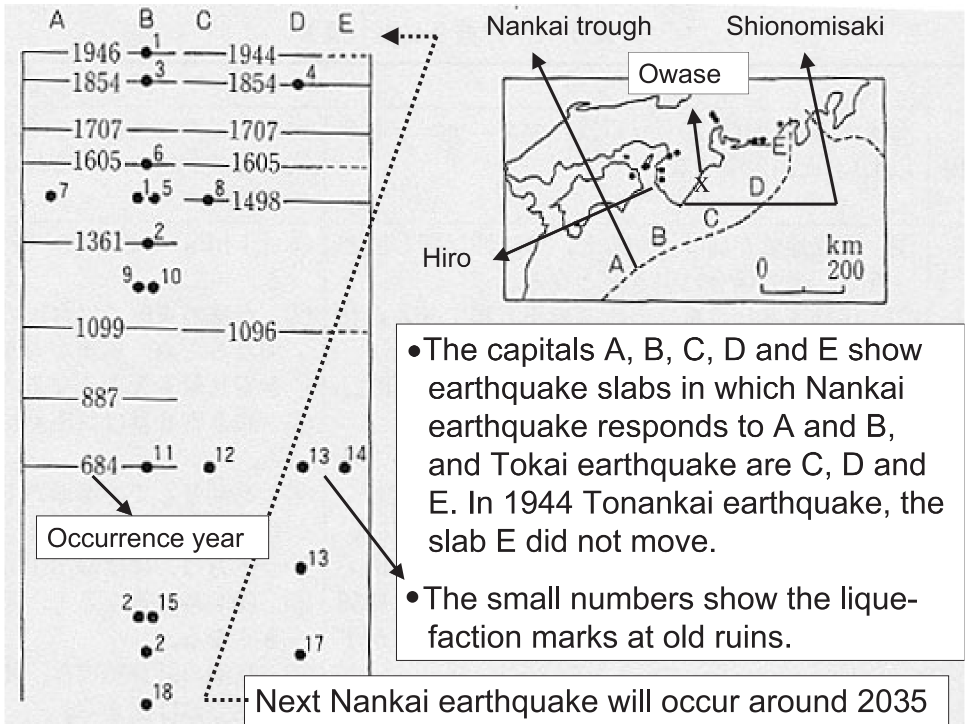

Figure 1: History of occurrence of Nankai and Toukai earthquakes after 684 and location of five slabs (segments) along Nankai trough and some local points.

and tsunami damage were not so huge (of course, the death toll was more than 1,300 and they were killed by tsunamis exclusively) in comparison with other cases. Therefore, our people usually forget the event. But the 1995 Hyogoken-Nambu earthquake (M 7.2, known as the Kobe earthquake) was explained as the introduction of the next Nankai earthquake. True to our prediction, the Tottoriken-Seibu earthquake (M 7.3) occurred on 6 October 2000 and the Geiyo earthquake (M 6.4) in 24 March 2001. Historically, during the 40 years preceding the Nankai earthquake, we had more than five inland earthquakes with a magnitude of more than 6 as shown in Fig. 2. Some of them are more than M 7. Therefore, we have to prepare tsunami countermeasures along the coasts in which the maximum tsunami height will be more than 10 m and the minimum arrival time less than 5 min. We have less than 30 years to prepare, as shown in Fig. 3.

This paper presents tsunami disaster scenarios that are necessary for producing a long-term tsunami measure policy and which, more importantly, have not yet been encountered in actual tsunami disasters in the world.

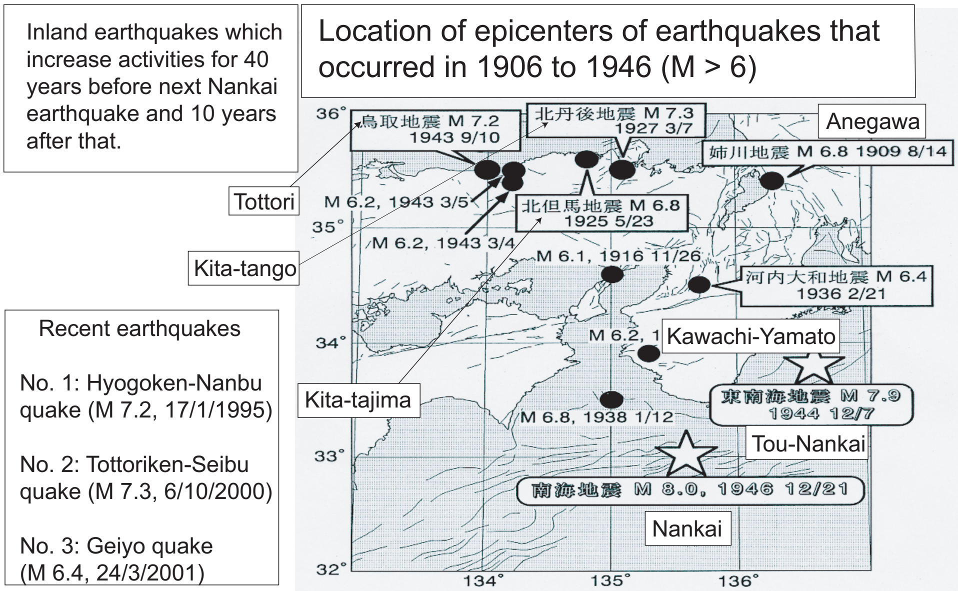

Figure 2: Inland earthquakes with a magnitude of more than 6 occurred between 1906 and 1946, 40 years before the 1946 Nankai earthquake and the three recent earthquakes after the 1995 Hyogoken-Nanbu (Kobe) earthquakes as an introduction of the next Nankai earthquake around 2035.

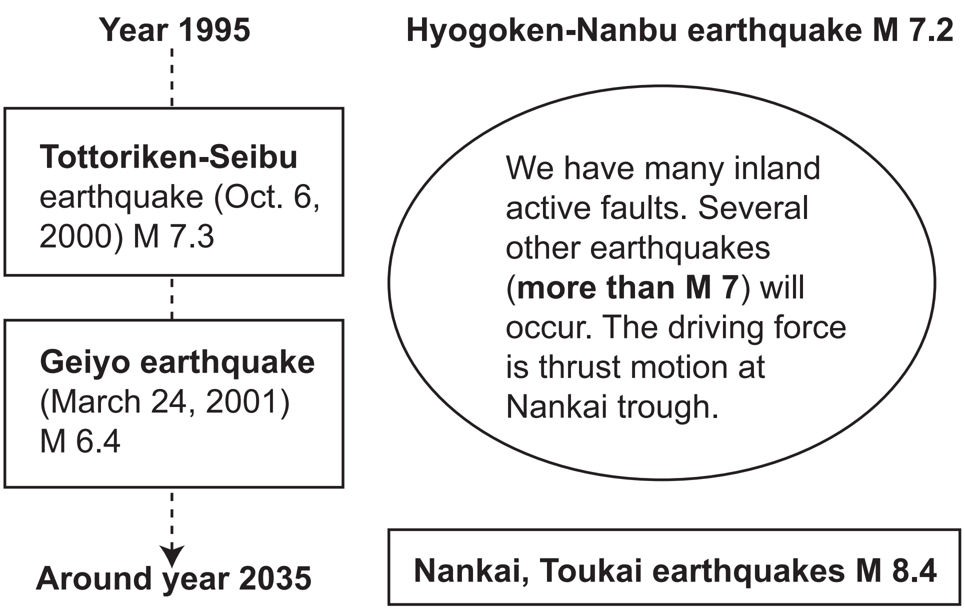

Figure 3: Simplified scenario of series of inland earthquakes before the next Nankai earthquake.

2. Current Tsunami Disaster Research in Japan

2.1 Recent tsunami disasters

Tsunami disasters have occurred frequently throughout the 1990s all around the world. Earthquake-generated tsunamis have struck successively over recent years in Nicaragua (September 1992), Indonesia's Flores Island (December 1992), the Hokkaido Nansei-Oki (July 1993), East Java (June 1994), and the Hokkaido Toho-Oki (October 1994). They also struck Northern Sakhalin (May 1995) and Irian Jaya, Indonesia (February 1996). In 1998, Papua New Guinea earthquake tsunamis hit the lagoon and killed about 2,500 residents. This number of human casualties due to tsunamis is the second largest in the 20th century. The common factor in all of these events was that the damage was confined to coastal villages and fishing harbors where the maximum population living on the tsunami flood areas was only less than several thousand people. They were all rural tsunami disasters. However, the "urban tsunami disaster" due to occur following earthquakes in the Nankai is expected to strike a wide and densely populated area that includes modern coastal cities and ports, resulting in a disaster of unprecedented proportions. Consequently, experts think it will be very difficult to apply the lessons of past tsunami disasters if an expansive area including residential coastal towns as well as low-lying urban regions with populations of hundreds of thousands or several million people is hit by a tsunami.

2.2 Recent efforts in tsunami disaster research

Because the purpose of tsunami disaster research is to minimize damage, research specifically pertaining to damage control is a top priority. To minimize injuries and casualties, individuals must evacuate the compromised region immediately following an earthquake. To evacuate, people need to have received accurate information regarding the tsunami threat ahead of time. The public needs the kind of information presented below.

1. What size tsunami should be expected where I live ? Will my house be in danger?

2. How long after an earthquake will a first tsunami arrive? At first, the hypocenter of oceanic earthquakes is not so important.

3. How long will it take for the maximum force of the tsunami to hit? How long will it continue?

   Figure 4 shows the tsunami numerical waveforms at Nishiki, Owase, caused by the M 7.9 Tou-Nankai earthquake model. "Tou" means east. Along the Nankai trough, we have five slabs (segments) as shown in Fig. 1. Usually, the Toukai and Nankai earthquakes respond to plate boundary motion of C, D and E, and A and B, respectively. In the 1944 earthquakes, however, a M 7.9 earthquake occurred with plate motion of C and D. The east end plate E was not moved, therefore the earthquake magnitude was not 8.4. This is the first case in which only two slabs generated an earthquake.

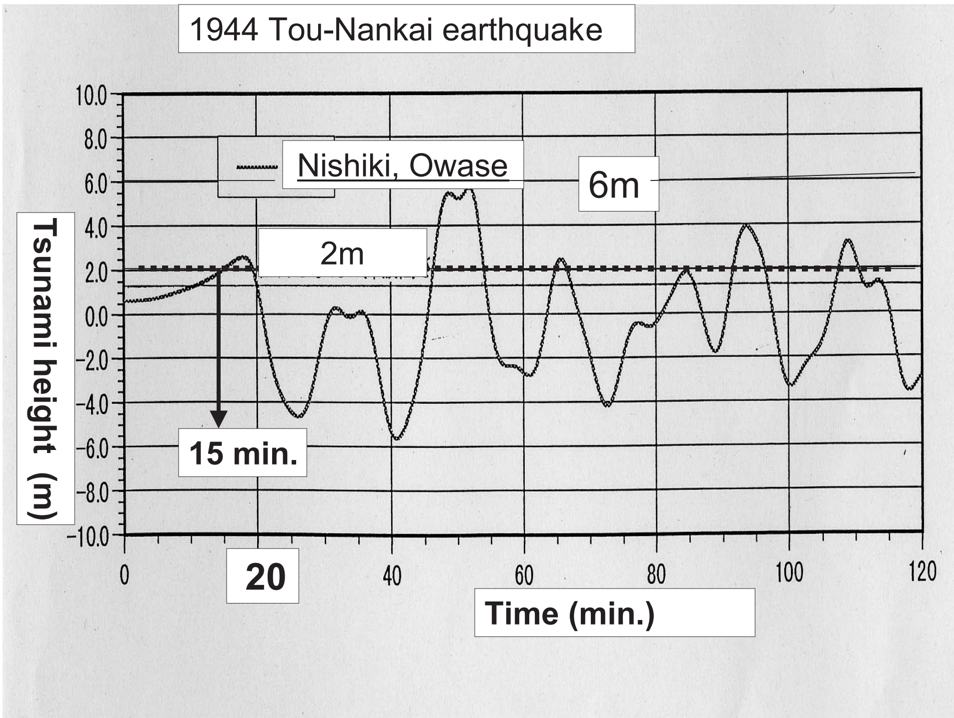

Figure 4: Wave profile at Nishiki, Owase in the 1944 Tou-Nankai earthquake model with a magnitude of 7.9.

The second tsunami wave at Nishiki was about double the first, as shown in Fig. 4. It was reported that after the 1944 Tou-Nankai earthquake, residents who survived the first wave returned to their homes to gather their valuables only to be caught in the second wave.

4. What is the worst case scenario should a tsunami strike our community? In a tsunami disaster, the first principle to follow is for each individual to look out for themselves. The next is for each community to look out for itself. Figure 5 shows the death rate (risk to life) resulting from various tsunamis. The data are only from tsunami disasters in Japan. Every symbol in the figure responds to the life loss data at small residential blocks or village units. This figure shows that early evacuation is very effective in reducing human casualties.

   The authors (Kawata and Koike, 1998) have tried to solve these problems by using the finite element method. It was applied to Hiro in Wakayama Prefecture. The sites of the "Inamura no hi" was described in nationally prescribed textbooks prior to World War II. This was the first example of a successful tsunami group evacuation controlled by town leader Goryo Hamaguchi. His good leadership contributed to no human casualties in Hiro. This figure shows the regional distribution of floodwater depth from the tsunami that resulted from the 1854 Ansei-Nankai earthquake based on the current topography of this region. The minimum value calculated for one side of the triangle using the finite element method is 2 m, and it takes into consideration minor waterways, the location of buildings, and a complex road network.

2.3 Challenge to organization for Nankai tsunami disasters and new concept for disaster reduction

In 12 October 1998 we organized about 350 members who are central and local government officers, employees of lifeline companies, and university researchers. Group membership is also available for central and local government departments and construction companies. This organization will continue until the next Nankai tsunami under the responsibility of the Research Center for Disaster Reduction Systems, Kyoto University. The author is presently President of this organization. The main purpose of our activities is to revise the Large-scale Earthquake Disaster Countermeasure Act established in 1978. This act is effective on a Tokai earthquake caused by slab E as shown in Fig. 1. Without our central government financial support, it is difficult to promote tsunami mitigation and preparedness in emergency management. Traditionally, we use risk management systems for disaster prevention ever since the 1923 Great Kanto earthquake disaster (the death toll was about 145,000), as shown in Fig. 6. Before the 1995 Kobe earthquake, disaster mitigation with structural engineering such as construction of tsunami breakwaters and retrofit of social infrastructure has been applied to prevent natural disasters. But natural forces can be greater than design measures are able to mitigate, and may increase damage. How to reduce damage is very important under this extreme situation. Soft countermeasures for disaster preparedness can reduce human casualties under conditions of extreme force. However, property damage cannot be reduced through the dissemination of disaster information. The combination, therefore of hard and soft countermeasures are essential.

3. New Damage Scenarios for Urban Tsunami Disasters

First, an explanation of the reason for the use of the term “urban” is necessary. A list of the tsunami disasters that have occurred in modern Japan in the order of greatest number of casualties appears in Table 1. However, these numbers include casualties caused by the related earthquakes as well. The areas hit by all of these tsunami disasters were local fishing villages or harbor towns with populations of less than one thousand, not modern and densely populated port cities. This tends to be the case around the world; past tsunami disasters have all occurred in relatively rural areas. However, it is possible that the next Nankai earthquake will cause serious damage above and beyond what has been seen in past tsunami disasters. New hypothetical damage scenarios are described below.

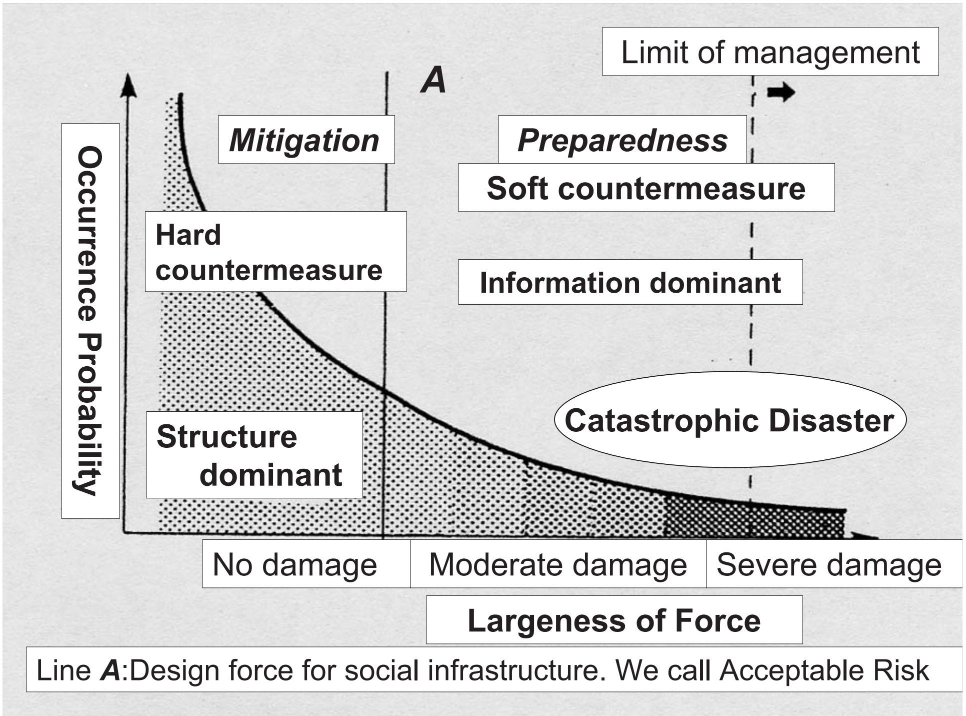

Figure 5: Risk management for disaster countermeasure in Japan. Concepts of mitigation, preparedness, hard countermeasure, soft countermeasure, and acceptable risk included.

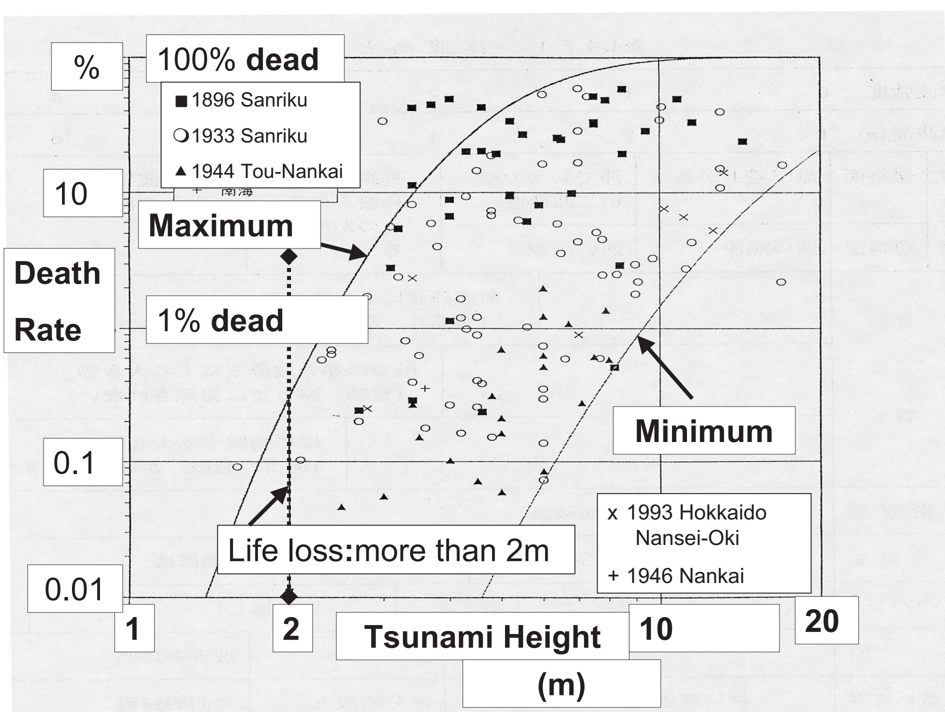

Figure 6: Relationship between tsunami height and death rate in Japan.

Table 1: Tsunami disasters in Japan in order of greatest number of casualties.

Order	Year	Name of Tsunami	Human lives lost
1	1886	Meiji Sanriku	21,959
2	1933	Showa Sanriku	3068
3	1946	Nankai	1330
4	1944	Tou-Nankai	1223
5	1993	Hokkaido Nansei-Oki	230
6	1960	Chilean earthquake tsunami	142
7	1983	Nihonkai-Cyubu	104

3.1 Possibility of a tsunami that exceeds estimates

The wave height and arrival times of a hypothetical tsunami were calculated based on a M 8.4 earthquake with the same hypocenter as the 1944 Tou-Nankai and 1946 Nankai earthquakes. Thus, there are at least two possible tsunami scenarios that would exceed current estimates. The first would be if the earthquake hypocenter were to shift eastward or westward, and the second would be if the earthquake were of a magnitude greater than 8.4. Seismographic records showing the earthquake's hypocenter are only available for the 1946 Nankai earthquake. The hypocenter for earthquakes of magnitude 8 or larger prior to this have been estimated from the attributes of the resulting tsunamis. Accordingly, their accuracy is not as reliable as that of the 1946 Nankai quake. These results suggest that the hypocenter may be distributed over a 200 km east-west stretch. On the other hand, indications suggest that fault ruptures from a Tou-Nankai or Nankai earthquake occur not in a disorderly fashion, but that they have a definite pattern. This means that it is reasonably safe to assume that the hypocenter will actually be fixed. Given the above issues, though, the location of the hypocenter is still a topic of debate, and it is impossible to assert that it will be fixed with absolute certainty.

In the latter scenario, if a Tou-Nankai earthquake and Nankai earthquake were to occur simultaneously (as is said to have happened in the 1707 Hoei earthquake), an earthquake of M 8.6 is estimated to occur. Calculations for this case suggest that the height of waves reaching Osaka Bay coastal regions would be 20% greater than in an 8.4 quake, while the arrival time of the first wave would not be significantly changed. Even in this case, it does not appear that the waves would spill over sea walls or embankments located in all of the outlying areas. It is still unclear whether a relationship can be established with the fault parameters for all magnitude 7 or higher earthquakes. All indications suggest that the possibility of a tsunami that will exceed current expectations cannot be ruled out.

3.2 Inundation flows through flood gates and sea walls

In outlying coastal areas and areas adjacent to rivers in Osaka Prefecture, there are an estimated 900 flood gates for storm surges. Since it takes about 6 hours to shut down all gates, the Japan Meteorological Agency (JMA) in the Osaka branch will issue a storm surge warning more than 6 hours prior to a storm surge arriving in Osaka bay. With the exception of those that are directly maintained by the Prefecture and City of Osaka (total number is less than 30), most of these gates and walls are privately maintained. Although according to standard practice, they are supposed to remain closed when not in use, most of them actually tend to remain open. If a hypothetical Nankai earthquake were to occur, the degree of ground motion in the outlying areas of Osaka Prefecture is expected to be about the same as that experienced in the Hyogoken-Nanbu earthquake. Accordingly, it may become impossible to close several of the existing flood gates and sea walls.

It must therefore be assumed that if a Nankai earthquake tsunami were to occur under the current conditions, some water would pass through the flood gates and sea walls. Past records indicate that if a tsunami hits, the upstream regions will be inundated in areas whose ground level is the same as or less than the tsunami height. Therefore, areas less than 3 m above sea level will be in danger of flooding. However, since the water will be entering through flood gates and sea wall openings, the flow discharge to inundate the hinterland will be determined by the product of the cross sectional area and the current velocity.

3.3 Damage to harbors and vessels

Damage to port facilities by a hypothetical tsunami, caused, for example, by sea walls breaking apart, is not expected to occur as long as the tsunami does not spill over barriers. Damage may be sustained, though, if waves cause moored vessels to roll and pitch, knocking them against the wharf or running them aground. Because the tsunami would reach, for example, the southern coastal areas in Osaka Prefecture 1 hour after the earthquake, and Osaka harbor about 2 hours after the quake, it will probably be impossible to remove moored vessels from the harbors in time. In terms of injuries and casualties, at least two scenarios are possible. The first involves casualties resulting from boats underway along the coast being tossed about by the tsunami and thrown against sea walls or flood barriers. Small vessels underway upriver may encounter collapsed bridge piers or, worse, collapsed bridges and water gates. The broken fuel tanks of damaged ships leak and spread out C-type heavy oil in the sea. This would be a source of environmental pollution and could spark an urban fire.

The second scenario involves relatively large moored vessels being run aground by the tsunami. Usually, clearance between the bottom of big vessels and the sea floor at wharfs is less or around 2 m so that some of them may run aground. They may be swept toward the shore with following waves and cause damage to the sea walls and other constructed barriers along the coast. Because the extent of damage in both of these scenarios depends on the size of the vessel, the larger the vessel, the larger the danger that large volumes of water will be allowed to reach the shore. Also, if any of these vessels is an oil tanker or a liquid natural gas tank, oil or gas may leak and/or ignite, creating the potential for a widespread fire. This could cause serious damage depending on the extent of the incident.

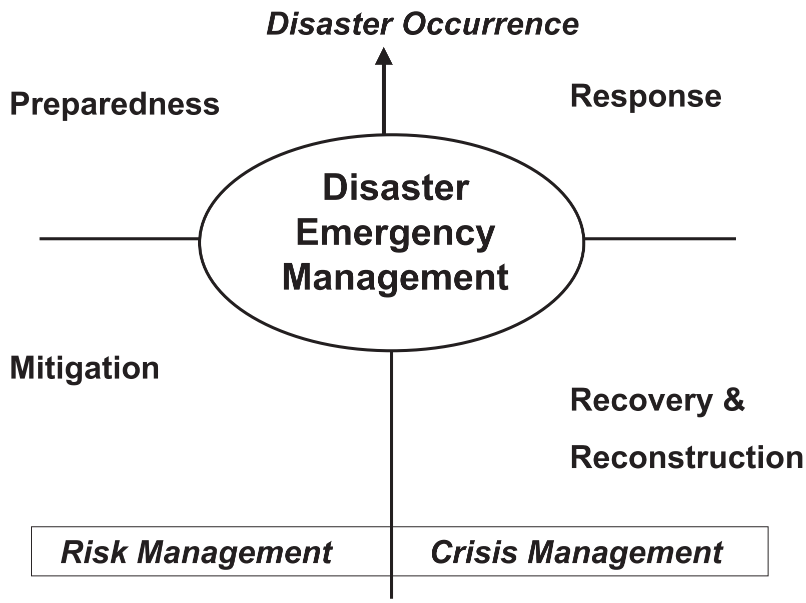

Figure 7: Schematic diagram of disaster emergency management divided into four parts.

3.4 Evacuees

It is believed that since the Toukai and Nankai earthquakes would not likely fully or even half destroy houses, there would be no need for area residents to evacuate to shelters. Tsunami warnings should explain how people should respond. First, those residing in flood-prone areas along the coast should go to designated emergency shelters (schools and other public facilities) or to the third floor or higher of iron-reinforced concrete buildings in their neighborhood. Next, there are several problems that must be handled and tasks that must be done once the tsunami warning has been announced. Because the tsunami will go upriver, it is necessary to make absolutely certain that residents do not evacuate to areas close to the riverbed. Also, in Osaka, for example, within just under 2 hours after a Nankai earthquake, the south and north underground malls must be closed because the number of passengers is more than one million per day. The Osaka Municipal Subway, Hankyu, Hanshin, Keihan, and JR-West lines must be moved from their underground tracks to aboveground areas. Access to basements and underground parking lots of buildings must also be restricted.

4. Tsunami Disaster Prevention Framework for Emergency Management

Emergency management for natural disasters is composed of four parts, as shown in Fig. 7. The first part is risk management, which includes mitigation (hardware installation) and preparedness (systematic preparations), as already pointed out. The most important aspects of risk management are risk assessment, land use management (including regulations, management, and development), and a damage estimate system (mapping, evaluations). Among the damage prevention measures involving hardware installation, the construction of tsunami prevention breakwaters has especially high costs, making it financially impossible for such barriers to be installed in areas around the nation that frequently experience tsunamis. Besides, they are not completely effective against tsunamis that exceed the scale for which they were designed.

Next, there is crisis management, which includes emergency response (when a prompt or urgent response is necessary), recovery and reconstruction, and social mitigation. The order of these five responses is called the chronological model. It is important to remember that tsunami disaster prevention differs from other flood disasters like storm surges. Once a tsunamigenic earthquake occurs, the stricken region will be safe for a significant period of time following the disaster because the energy of the earthquake was expended. This fact is inconsistent with the premise of the Basic Disaster Measures Act established in 1961, which is to prevent a disaster from being repeated a second time. When tsunami disasters occur, they tend to be in a different location from the site of their last occurrence. For example, in all areas of Okushiri, which sustained severe damage in the 1993 Hokkaido Nansei-Oki earthquake-generated tsunami, tsunami prevention sea walls averaging more than 10 m above sea level (exactly the tide position in the middle of Tokyo Bay T.P. plus 11.5 m) have been constructed. But, the location of the epicenter of the next earthquake to occur at the interplate boundary of the North American and Eurasian plates will likely be in a different location from the 1993 quake. Researchers fear that the next tsunami disaster will occur in a different region from the last one. This is especially disturbing since the regions that were unharmed last time still have unprotected coastlines and are very different from the affected region. It is thus crucial that tsunami disaster prevention efforts recognize that the specific circumstances surrounding a flood disaster will differ by region.

5. Tsunami Disaster Prevention As It Should Be

5.1 Earthquake-resistance reinforcement of homes necessary for tsunami disaster prevention

Because the human casualties resulting from tsunamis exceed those resulting from the earthquakes that generate them, as was the case in the 1983 earthquake-generated tsunami in the central Sea of Japan and the Hokkaido Nansei-Oki earthquake-generated tsunami in 1993, the analyses of these events tend to focus on the former and exclude the latter. After an earthquake-generated tsunami like the 1896 Meiji Sanriku tsunami, it would certainly be reasonable to think of disaster preparedness measures only in terms of the effects of tsunamis. In a Tokai or Nankai earthquake-generated tsunami such as is now anticipated, however, history suggests that the Pacific coast of western Japan would experience an earthquake of at least a seismic intensity of approximately 6, and as high as a magnitude 7 in some places, thus yielding serious earthquake damage even before the tsunami's arrival. This means that we must be prepared to face reduced access to narrow roadways due to obstruction by collapsed residences and must realize that bridges and elevated highways may be unusable.

After the Kobe earthquake, local governments provided some financial assistance, however little, for conducting seismic resistance evaluations on private residences, but it has been reported that few, if any, homes were actually seismically reinforced. There were five cases that I know of during the Kobe earthquake in which a passer-by, like a newspaper delivery person, was killed by a toppling home. It is tragic when someone is killed in their own collapsed home because they chose not to reinforce it, but it is an even greater tragedy when someone on a public street is killed by the collapse of another person's home. That is, if one of the earthquakes mentioned above occurs during the day, many pedestrians will likely become fatalities. Therefore we must devise measures in advance for what to do when a damaged house threatens to collapse onto other properties or into the roadways. If someone is killed because a building owner chose not to seismically retrofit a structure in spite of being aware of the potential danger, that owner may be charged with a crime or may be subject to a civil lawsuit. If something is not done quickly to seismically reinforce private residences, our cities will continue to be in danger of sustaining as many or more earthquake fatalities as resulted from Kobe earthquake, depending on the hour the temblor strikes. Clearly tsunami disaster preparation must be either preceded by or at least accompanied by earthquake preparedness efforts.

5.2 What constitutes tsunami disaster prevention?

Next I would like to discuss the specific components of tsunami disaster prevention. For emergency management, we need three "knowings" such as follows in Fig. 8:

1. Knowing hazard (understanding mechanisms of tsunamis),
2. Knowing vulnerability (recognizing weaknesses from social or physical points), and
3. Knowing countermeasures.

"Knowing hazard" is the premise of tsunami disaster prevention and requires a correct understanding of why tsunamis occur and how they behave. When a tsunami warning is announced during the summer swimming season, swimmers must return to shore. If even a wave of only 20 to 30 cm in height extends over the length of several tens of kilometers, it could carry a small

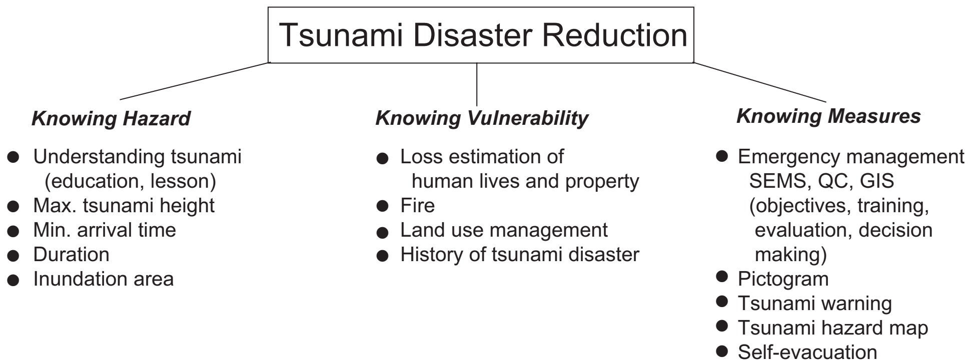

Figure 8: Three "knowings" in tsunami disaster reduction.

child floating in a life preserver over a kilometer away from shore. Current tsunami warnings give the false impression that the only danger to be aware of is wave height. Falling rock warnings are similar. They warn people to watch for rocks that have fallen in the road, but do not warn people to be aware of rocks that may soon fall in the road.

We must be aware that lessons are by definition learned from specific past experiences and thus may not be generally applicable across situations. In Owase, Mie Prefecture, for example, mathematical calculations indicate that the largest wave following a Tonankai earthquake will be the third (arrival time: about 50 min after the quake), even when the quake magnitude is changed in increments of 0.5 from 7.9 to 8.4. Accordingly, survivors of the first wave of the 1944 Tonankai quake (which arrived about 11 minutes after the quake) may erroneously say that there is at least a 30 minute lag time between the earthquake and the tsunami's arrival. It is important to remember that this is not always the case, however, and that the arrival time will change depending on the location.

The minimum amount of information the general public needs for evacuation purposes is the maximum wave height, and the earliest time at which that wave could reach shore. Clearly even the quantitative predictions of the Meteorological Agency that were revised in 1999 are inadequate for this purpose. It is also important to know how long the tsunami will continue. In recent years, the increase in the number of weather announcements and the poor timing with which announcements and cancellations have been made have come under fire, but since tsunami information is announced from district meteorological observatories, it is no surprise that a smooth and efficient response is difficult to achieve. Institutions involved in disaster prevention should be expected to make efforts to determine the intervals between tsunamis using advanced mathematical calculations and historical records. When flooding occurs, it is important that the public is forewarned of how far inland the floodwaters will reach, and that instruction boards with pictures are made available for tourists and other non-residents unfamiliar with the area and for foreign nationals who cannot read Japanese.

Pictographs are very effective in reducing human casualties from tsunami flooding.

"Knowing vulnerability" means knowing the approximate degree of damage that will result from a disaster. In terms of human casualties, early self-evacuation is more important than any other factor, so estimation of maximum and minimum human casualties are especially important. Physical damage assessments must be reflected in long-term urban and regional planning measures.

Also, if a large tsunami occurs, the threat of fire must not be forgotten. Fires may break out when:

1. houses are destroyed by the earthquake,
2. fishing vessels or steamboats are washed ashore and topple over, igniting fires and spreading fuel and oil supplies, and
3. fishing vessels or steamboats are thrown against seawalls or wave barrier blocks, cracking their fuel tanks and spilling fuel that can ignite. Spilled oil may also pollute the environment over a wide area.

Finally, we need "knowing countermeasures." First let us examine the components of emergency management. Standardized Emergency Management Systems (SEMS) is a standardization of systems for conducting emergency management. In cases of a tsunami disaster across a wide area, SEMS requires that the affected local governments work together to handle the situation. If, however, each government has its own emergency management system, the advantages of cooperation will not be realized. In the state of California in the U.S., the shared emergency management system is a Lotus Notes based system that links the Federal Emergency Management Agency, the state government, and the county and city halls. Since forecasts indicate that more than 10 prefectures would sustain serious damage if a Tonankai and Nankai earthquake were to occur simultaneously (as has happened twice in the past), it is essential that efforts toward this kind of standardization begin now.

QC refers to quality control in regional disaster prevention plans, and includes the specific goals, practice drill programs to achieve these goals, a progress evaluation system, and the determination of decision makers that were mentioned in section two above. In essence, there is concern that the regional disaster prevention plans that have been created to satisfy those involved in local government will be useless when put into action. Geographic Information Systems (GIS) are just that, overproduced systems that cannot be easily operated or revised. Ironically, these deficiencies are obvious to those governments that paid for them. Around the time that these systems began to be constructed, people were generally unaware of the information described in section two above. Consequently, the current disaster prevention GIS, in extreme cases, projects insufficient information gathered from a 100-inch CRT that is seen by no one other than disaster prevention personnel.

This article has not approached the topic of the installation of hardware like tsunami prevention sea walls because of the number of serious disadvantages in terms of cost effectiveness of such measures. The development of a measurement system that uses tsunami recorders and seismographs is by far a more effective way to bolster disaster prevention efforts.

The importance of self evacuation was mentioned earlier. As long as we are under the false impression that the provision of "accurate, fast, and detailed" tsunami disaster information will decrease the number of human casualties, the results of bolstering these systems will be negligible. Information is no more than one factor in the communication process, and if we do not know how to use the information we have in the stages between the communication of risk before a disaster and the follow-up communication afterward, the same mistakes will be repeated over and over again. Today the self evacuation advice given during flood warnings is largely ignored in the regions at risk, and there have been reports of not a single person going to an evacuation shelter. Tsunami hazard maps are being prepared, but unless the purpose for which these are being designed is clarified in advance, they will end up being used as mere roadmaps.

6. Conclusions

Historically, the Nankai earthquake has a clear period of pre-disaster 40 years and post-disaster 10 years. In this 50 years, we will have several inland earthquakes with a magnitude of more than 7. Unfortunately, the 1995 Kobe earthquake was the first gateway to the next Nankai earthquake. If it will occur in or around 2035, the earthquake magnitude will be a full 8.4 or more. This earthquake will be accompanied by huge tsunamis which will hit densely populated coastal areas with a population of more than ten million facing the Pacific. We have only 39 years for disaster reduction. In this tsunami disaster, we will primarily have urban tsunami disasters. According to new damage scenarios, loss of human lives may be over ten thousand and property loss over ten thousand billion U.S. dollars. At that time, our country will have a greater number of aged people, making adequate response and recovery difficult. There are many tasks involved in preparing for this tsunami disaster, and it is important that each of these be diligently executed. If, however, we assume that the general public is not aware of this, our most important task may be to develop tools to help them easily understand what has been written here.

7. References

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